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The Effect of Impeller/Cutwater Clearance on Pump Vibration

by:

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Author Biographies

Lyn Greenhill is the President of DynaTech Engineering, Inc. a consulting firm focusing on rotating equipment dynamics problems for industrial and aerospace technology customers. Prior to founding DynaTech in 1995, Mr. Greenhill was employed as the Chief Engineer for a consulting company, a Senior Engineering Specialist for rocket engine manufacturer, and as an engineer and supervisor for a gas turbine company. He has authored 16 technical papers in the areas of rotor dynamics, machinery vibration, rolling element bearing mechanics, and turbine blade damping. He earned BS and MS degrees in ME from Stanford University in 1975 and is a Registered Professional Mechanical Engineer in the State of California.

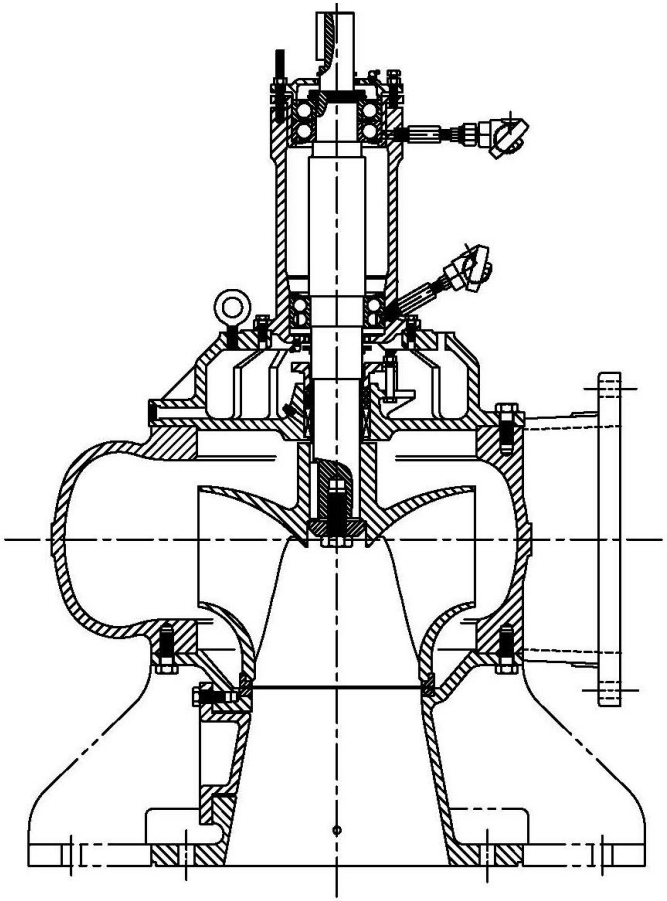
Valerie Lease is a Senior Mechanical Engineer at DynaTech, responsible for core engineering activities such as creating and running finite element and rotor dynamics analysis models, reducing vibration test data, and writing engineering reports. She started with DynaTech in 1999 while finishing her BS degree in ME at UC Davis, earned a MSME in 2004 from Cal State at Sacramento, and has co-authored 3 technical papers.

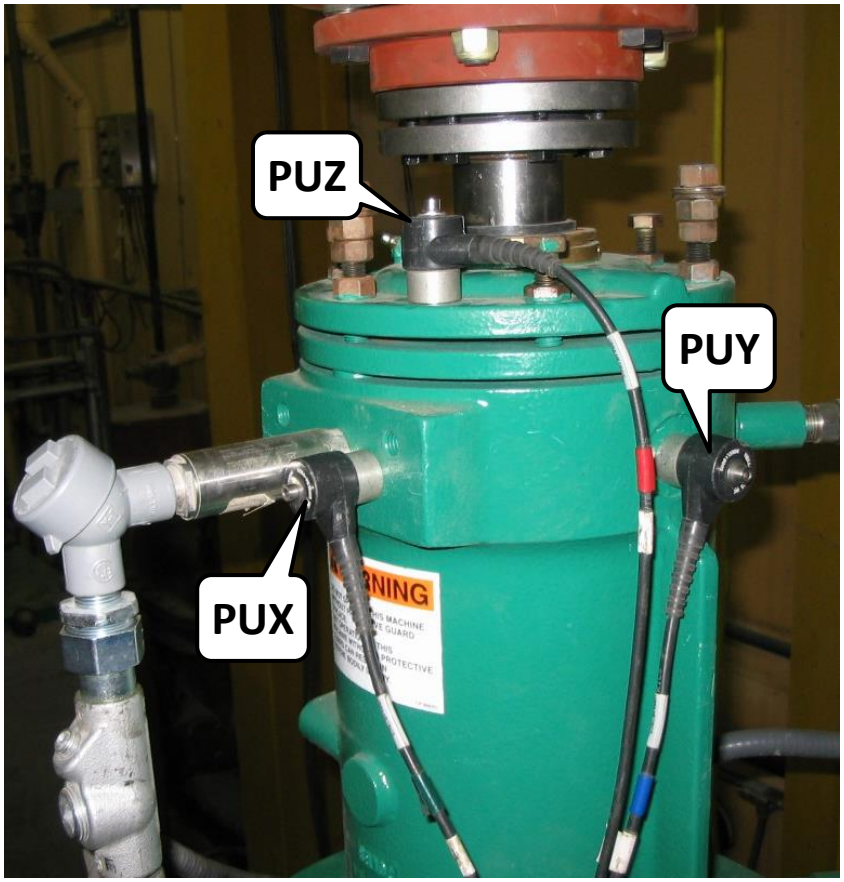
Ali Rozati is the Manager of CFD Engineering Services at the CD-adapco California office. He has been with this company since 2009 performing CFD analyses for thermal management, bio-medical applications, and turbomachinery flow. Prior to CD-adapco, he worked for Modine doing flow and heat transfer simulations. He earned a PhD in ME from Virginia Tech in 2007.

Case Study Summary

- Newly installed vertical centrifugal pump failed vibration acceptance due to excessive vane pass
- Factory test vibration unknown
- Rotor dynamics and modal survey indicated no resonance issues
- CFD separation analysis showed high velocity at cutwater due to low B-gap
- Volute cut back to increase B-gap (no impeller trim)
- Vibration after cutback acceptable

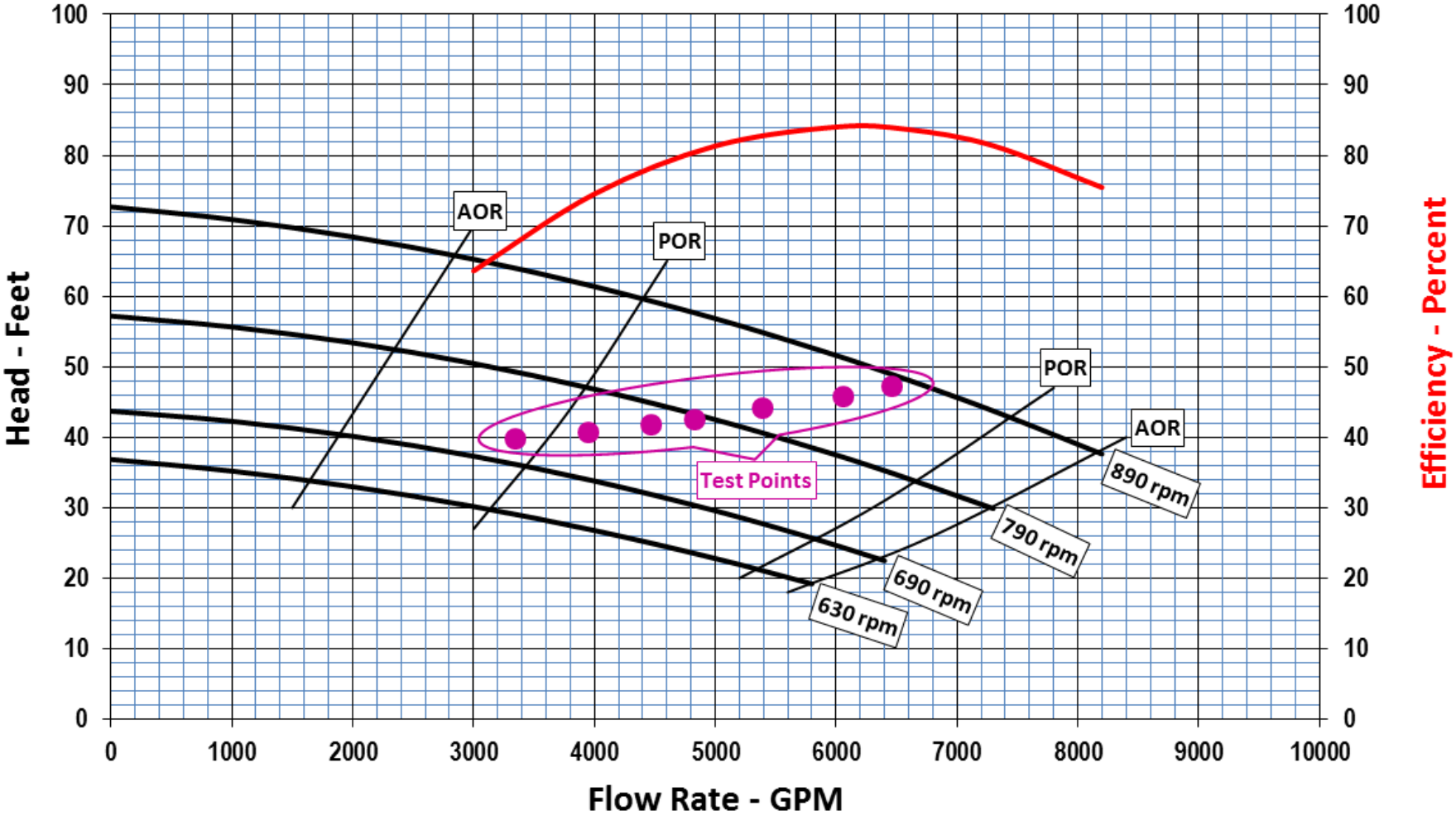
14” Vertical Centrifugal Pump



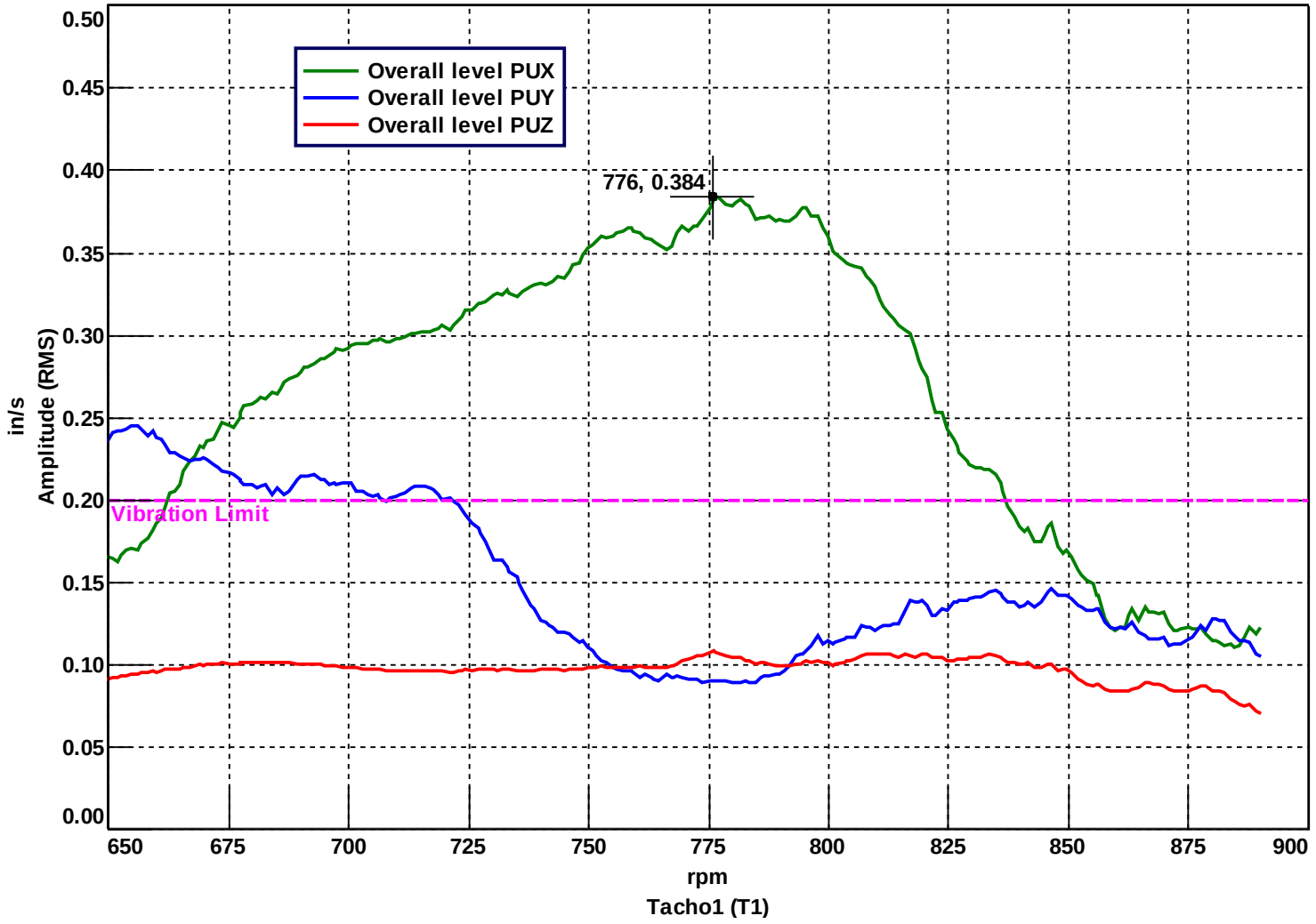


- 125 hp shaft driven wastewater pump
- 16.85” OD, 3-vane impeller, SSS = 7500

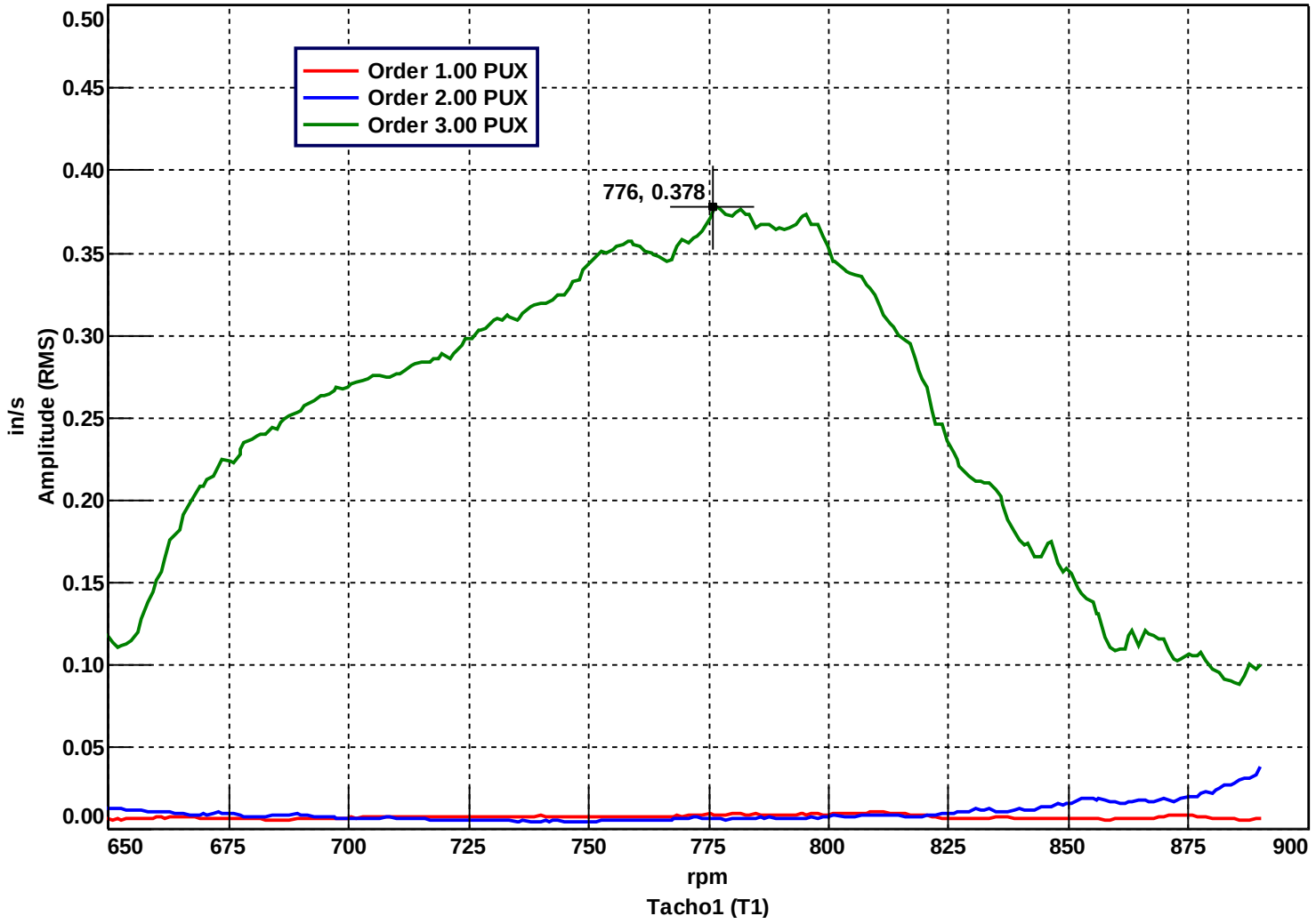
Pump Operating Conditions



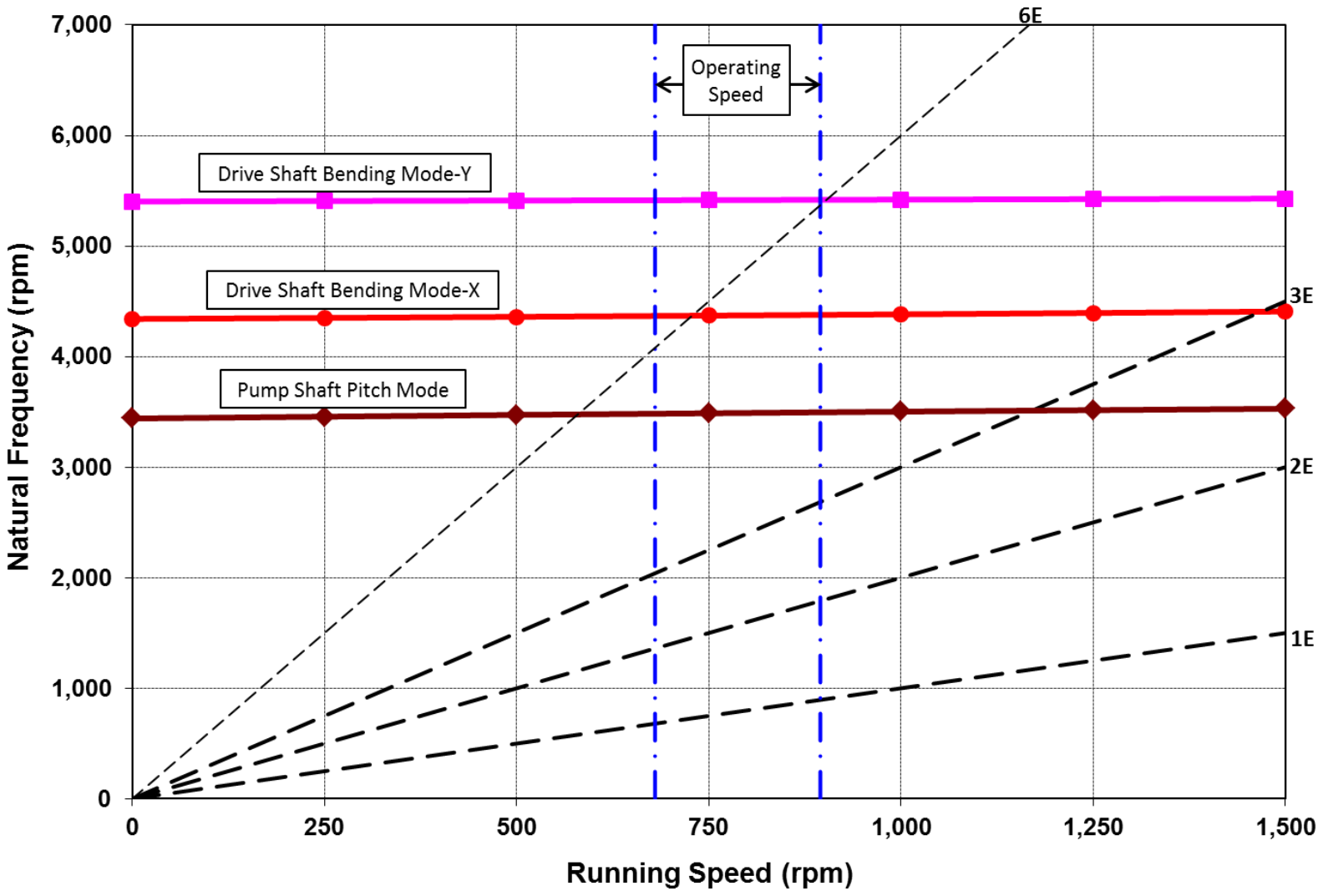
Initial Pump Vibration



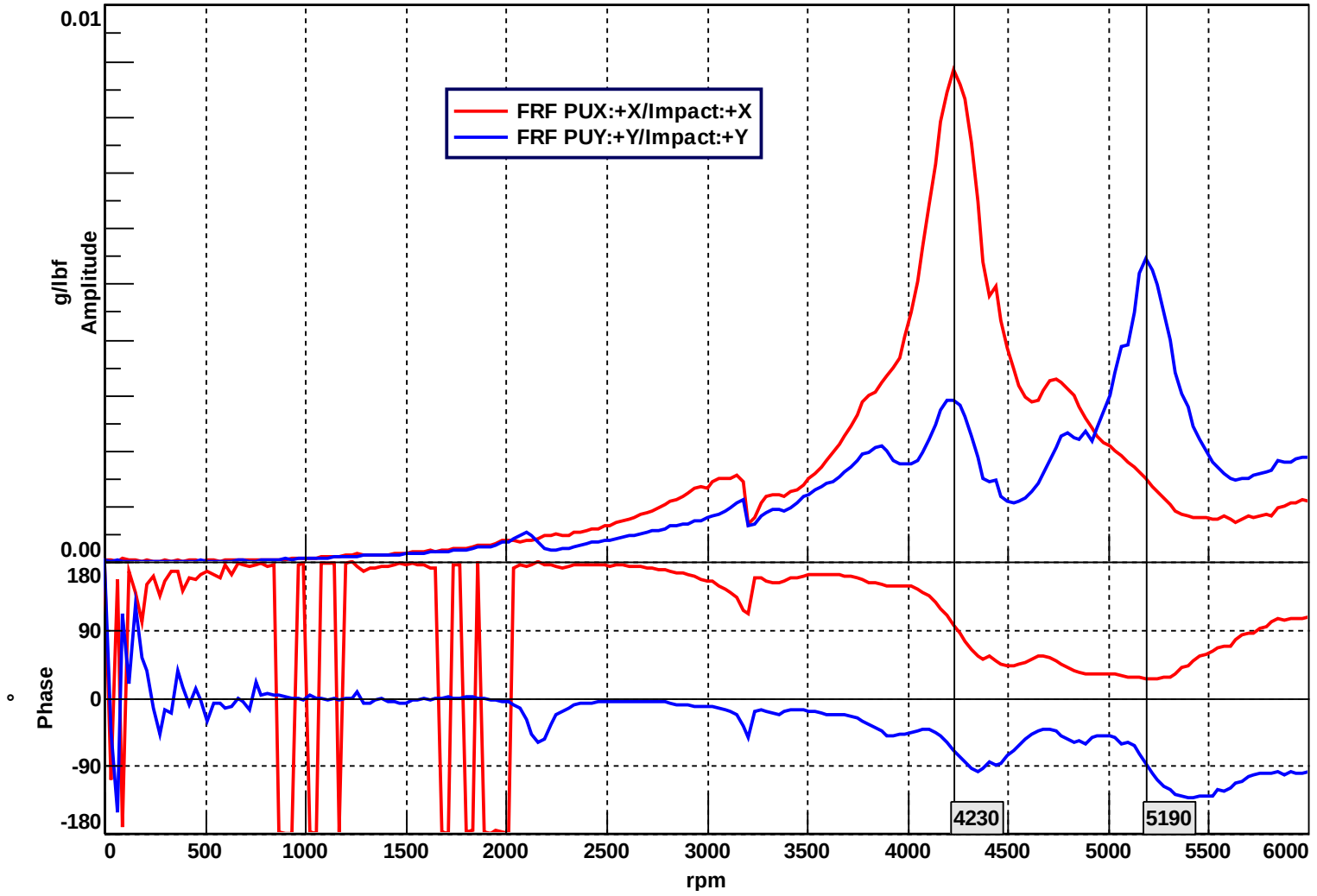
Initial Vibration Essentially All 3X



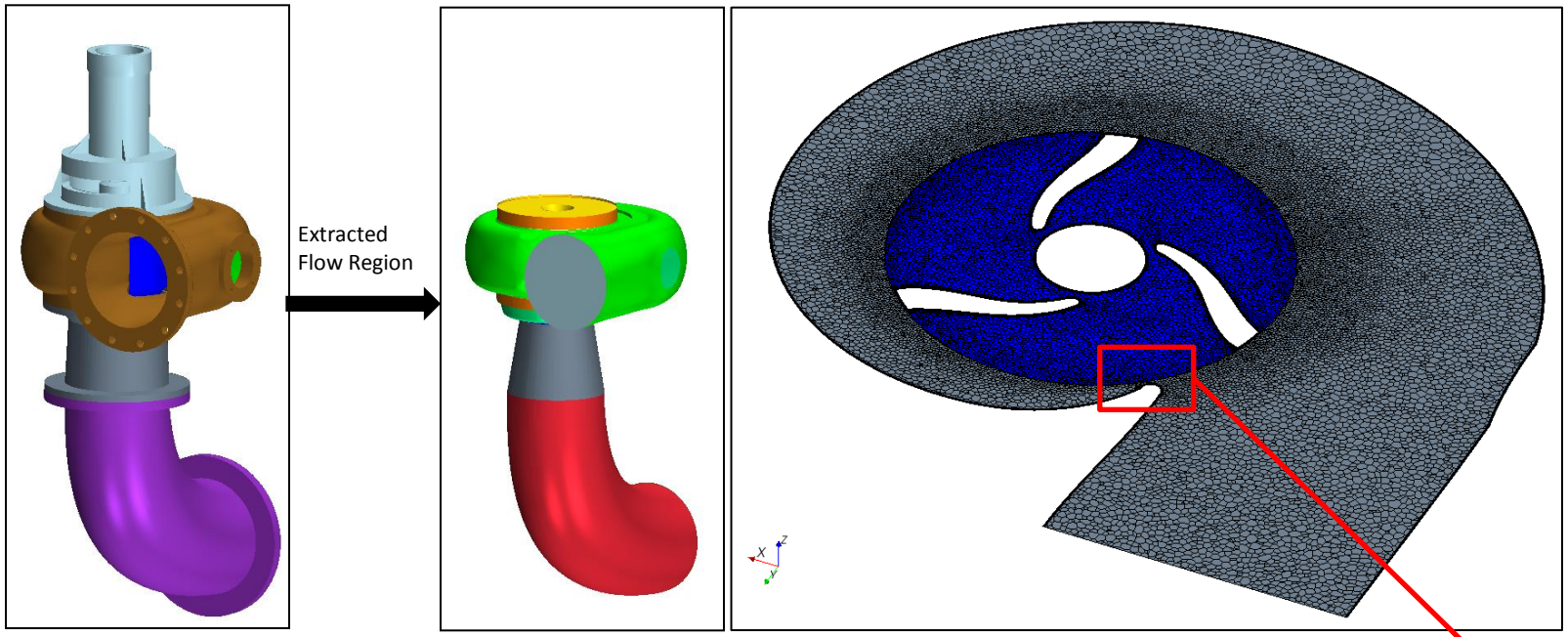
No Predicted Dynamics Issues

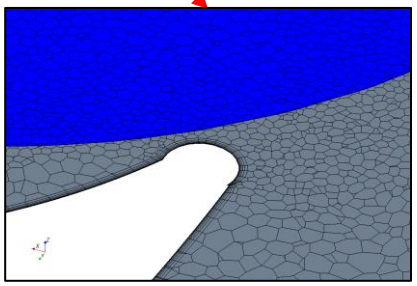


Modal Confirms Dynamics



CFD Shows Potential Solution

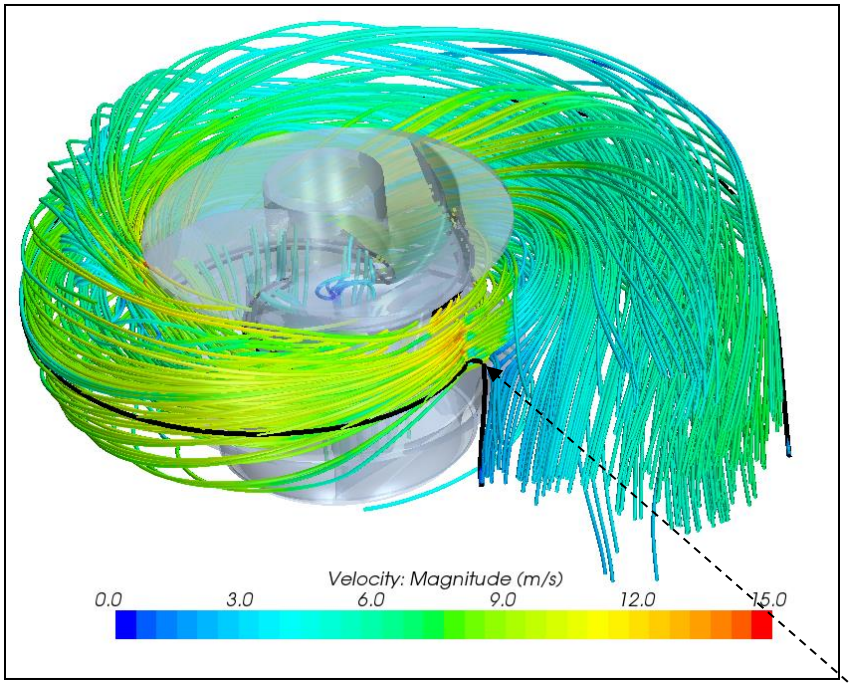




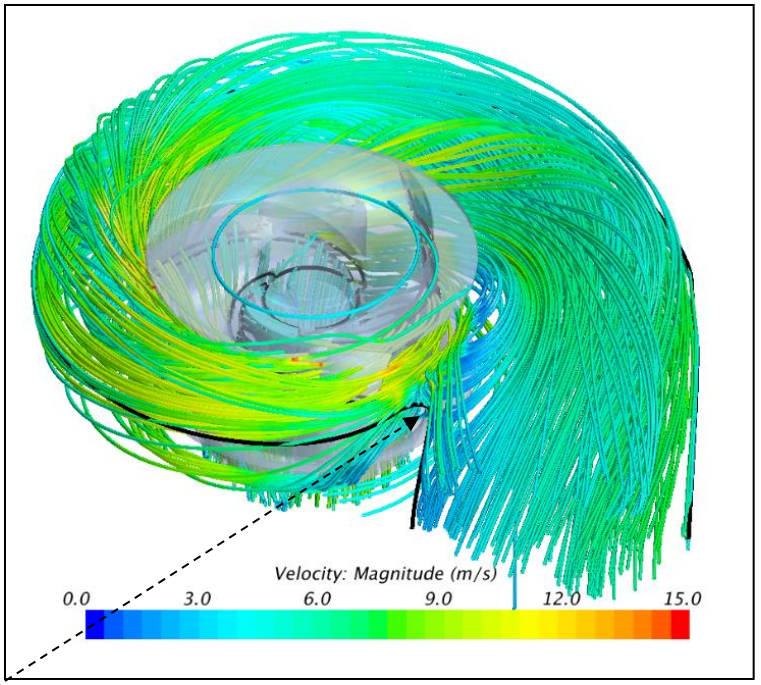
- CFD required for passage separation
- 14 M cells, moving reference frame
- Refined mesh near cutwater
- Low B-gap obvious in mesh view

CFD Results (800 rpm)

Original Pump
2.9% B-gap



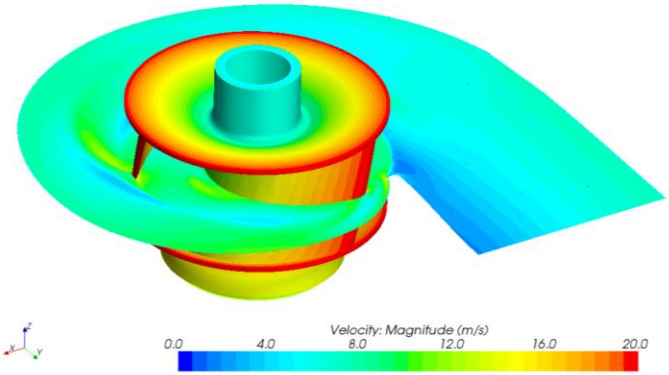
Modified Pump
7.0% B-gap

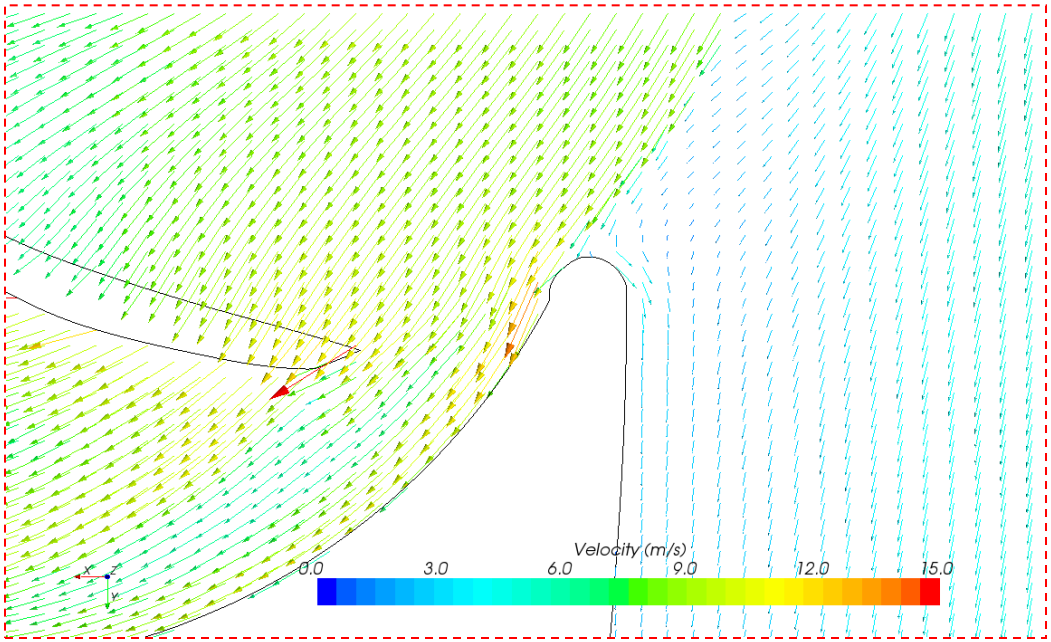


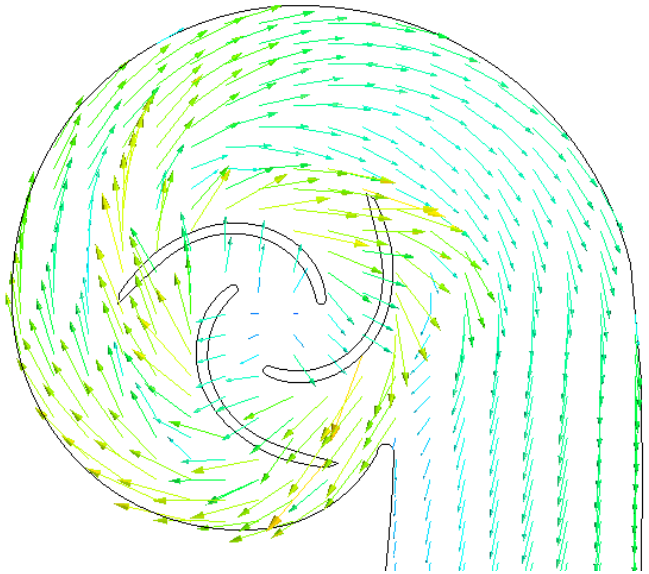
Lower velocity at cutwater in modified pump
=> reduced vane pass excitation force
(impulse-momentum)

Velocity Field – Original Pump

Vector plots show velocity of ~14 m/s at cutwater with original geometry

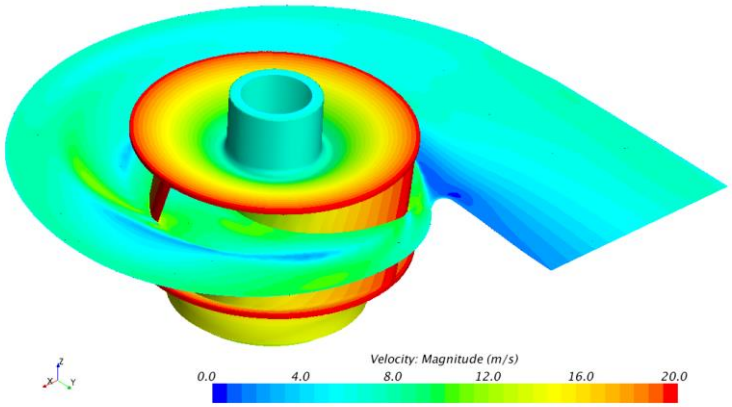


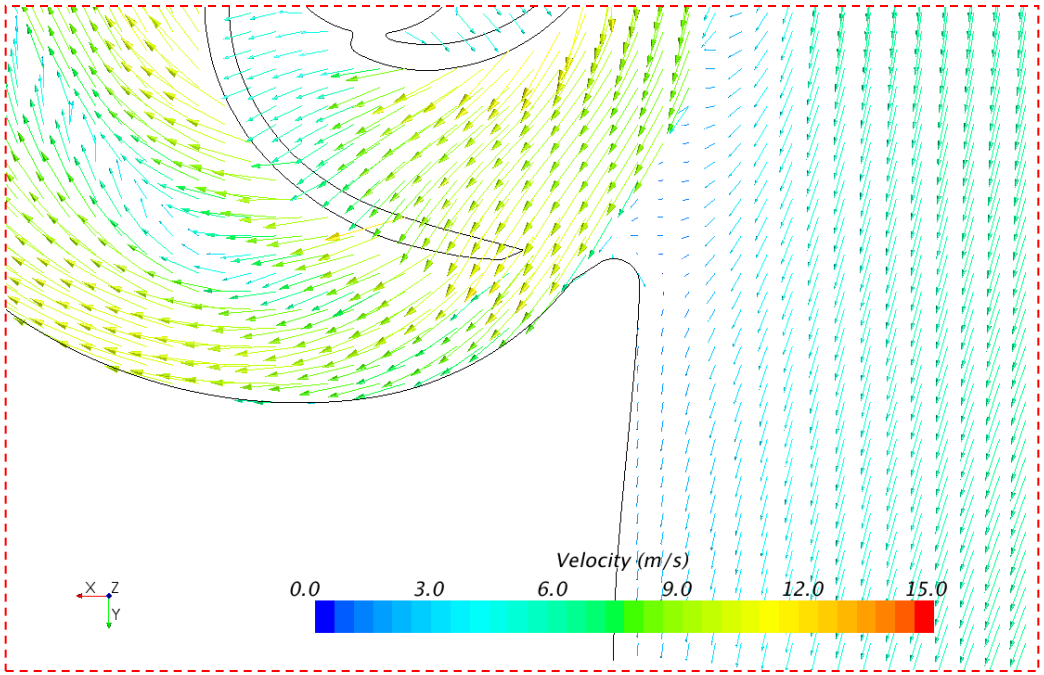


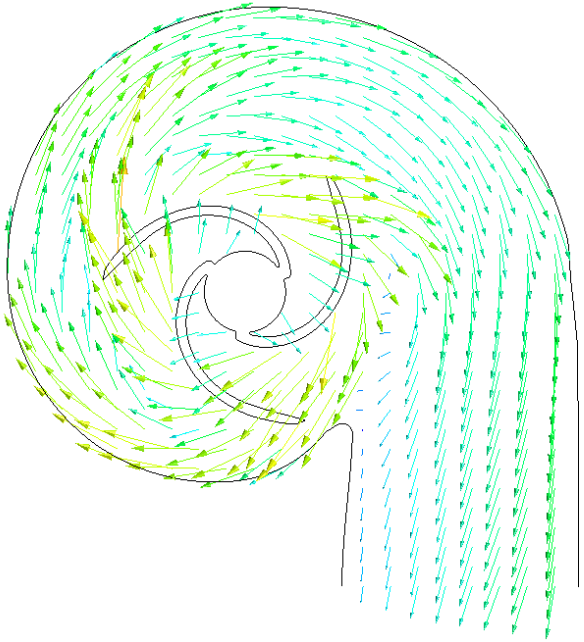


Velocity Field – Modified Pump

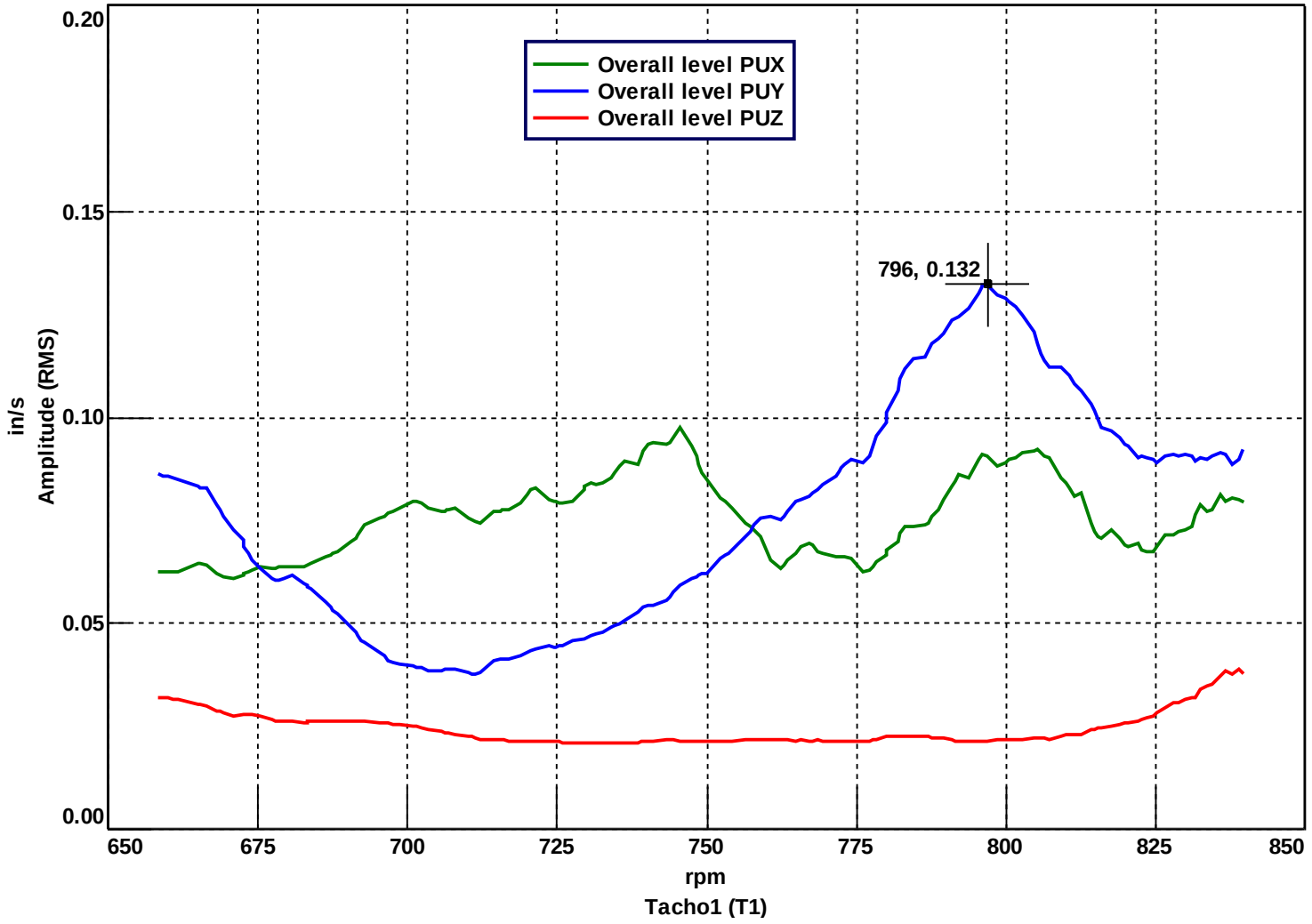
Vector plots show velocity near cutwater dropped to ~9 m/s for modified geometry



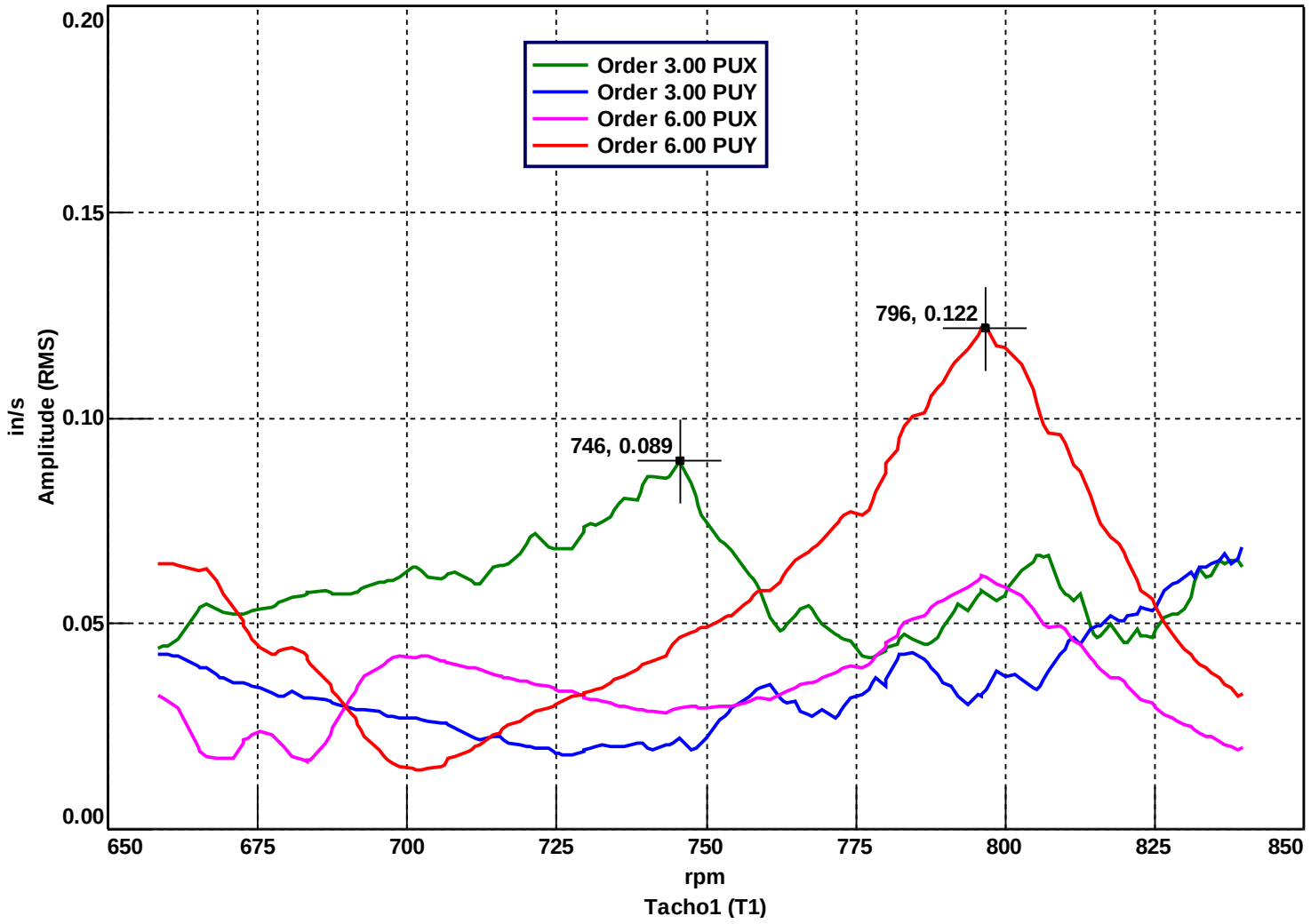




Modified Pump Vibration



Vane Pass Harmonics Dominate



Conclusions & Recommendation

- CFD predicted 36% velocity decrease at cutwater with an increase in B-gap from 2.9% to 7.0%
- CFD provided quantifiable results to pump manufacturer to justify unrecoverable modification
- 66% overall vibration decrease with B-gap increase
- Keep B-gap to 6-10% (Makay & Barrett, Gülich) to avoid excessive vane pass vibration

References

- Makay, E. and Barrett, J. A., 1984, "Changes in Hydraulic Component Geometries Increased Power Plant Availability and Reduced Maintenance Costs: Case Histories," *Proc. 1st Intl Pump Symp*, Texas A&M Univ.
- Gülich, J. F., 2010, Centrifugal Pumps, 2nd Edition, Springer-Verlag, ISBN 978-3-642-12823-3